SEGMENTAL VS SYLLABLE MARKEDNESS

DELETION ERRORS IN THE PARAPHASIAS OF FLUENT AND NON-FLUENT APHasics

DIRK-BART DEN OUDEN
University of Groningen

1. Introduction

Where phonological theory has been applied to clinical data, the concept of markedness has often played a significant role (Blumstein 1991). Not often taken into account, however, is the fact that the markedness value of linguistic structures may not be the same at all psycholinguistic levels of processing. What is marked at some linguistic level of representation may well be unmarked at another. In combination with currently maintained assumptions about the generation of aphasic (phonological) errors at different psycholinguistic levels (e.g., Kohn 1988), this finding allows for interesting and useful comparisons, through which the influence of different types of markedness on literal paraphasias may be related to specific psycholinguistic levels of processing.

For this study, we have compared the literal paraphasias of fluent and non-fluent aphasic speakers on a repetition task, aimed at determining the influence of syllable structure on error patterns. The results of both groups have been shown to be equal to a large extent (Den Ouden & Bastiaanse 1999 and in press), but the observed differences in complex coda cluster reductions lead us to conclude that different types of markedness apply at the different affected levels of processing in fluent and non-fluent aphasics.

Our analysis is in terms of conflicting and violable constraints, which leads to the application of phonological Optimality Theory (Prince & Smolensky 1993) to our data. An important section of this paper is devoted to possible and, in our view, necessary, adaptations to mainstream Optimality Theory, for it to correspond more closely to a plausible psycholinguistic model of speech processing and deal with aphasic data such as presented here.

The first section discusses phonological markedness, the background to this concept, and its application to the study of aphasia in general. The difference between fluent and non-fluent aphasia is explained and argued for in the second section. After this, we present the data obtained from a
repetition task and our analysis of these data, focusing on the difference between fluent and non-fluent patient groups in the reductions of coda clusters. This analysis is formalized in the fourth section, where we introduce Optimality Theory (OT) and discuss how its tools can be used to give plausible representations of our findings.

2. **Phonological markedness**
An important factor underlying the relative frequency of occurrence of linguistic structures in language is the markedness of such structures. In different languages, and also during the course of child language acquisition, more marked structures will be less widely distributed than less marked structures sharing the same domain.

According to Jakobson (1971), the sound system of a language starts off with the sharpest contrast between sounds, i.e., a wide vowel (usually /a/) and a stop with occlusion at the front of the mouth (usually /p/). In other words, vowels are as extremely vowel-like as possible, and consonants are as extremely consonant-like as possible. After this first acquired contrast, the next is that between oral consonants and nasal consonants. This order of acquisition is argued to be based on ease of articulation. The generally acknowledged least marked sequence of segment types, namely Consonant + Vowel (CV), however, is argued to develop because the phonemes “need to be correctly identified by the listener, and [...] the best grasprable clue in discerning consonants is their transition to the following vowels” (Jakobson 1971:25).

If markedness effects are the result of factors that are inherent to language, it is interesting to see what the role of markedness is in pathologies that are specific to language, viz. different forms of aphasia. Jakobson himself already stated that “[aphasic regression has proved to be a mirror of the child’s acquisition of speech sounds” (Jakobson 1971:40), when it really had not, but comparable arguments did spark off many research projects into the relation between markedness and aphasia.

Blumstein’s (1973) starting hypothesis was very Jakobsonian, in that she appears to have expected to find, and indeed did find, similar effects of the relative phonological markedness of segments in patients with different types of aphasic syndromes, as, “regardless of the area of brain damage, the more

---

1. Here we use the term *structure* to imply all phonological particles of analysis, i.e., features or feature combinations, segments or segment combinations, syllables or syllable frames, feet or combinations of feet, etc.

2. Evidence of CV as the syllable structure that is first acquired by children is provided by a number of authors, such as Smith (1973) and Fikkert (1994).
complex phonological structures are impaired and the less complex phonological structures are relatively preserved” (Blumstein 1973:136). Blumstein studied the error patterns in the speech of patients with Broca’s aphasia, conduction aphasia and Wernicke’s aphasia. In a nutshell, the phonological errors of Broca’s aphasics are claimed to result from the inability to translate a correct phonological speech plan into its correct phonetic counterpart and articulation. Conduction aphasics, in a very broad definition, mainly have (postlexical) problems with the sequencing of correctly retrieved sounds and sound patterns from the lexicon. Wernicke’s aphasics’ phonological problems are caused by deficient retrieval from the lexicon, or even by distorted lexical representations themselves. These three groups all made more errors on segments that had been classified as more marked beforehand. In segment substitutions, marked segments were generally replaced by less marked segments.

Besides segment type, studies by Nespoulous et al. (1984, 1987) took into account syllable structure. They found that the error patterns of Broca’s aphasics were generally constrained by the relative markedness of different segments and syllable structures, whereas such constraints were not found in the errors of conduction aphasics.

Such results of studies into markedness and aphasia lead to hypotheses about the nature of markedness. If aphasic deficits exist at different levels of language processing and markedness effects can be related to specific aphasic syndromes and therefore to specific levels of processing, this deepens our knowledge about the origin of markedness effects.

One problem, of course, lies in the fact that aphasic syndromes are far from ‘specific’ (e.g., Poeck 1982; Ellis & Young 1988). Also, as noted by Nespoulous et al. (1984, 1987), if phonological markedness at underlying, abstract levels of processing is heavily influenced, or indeed formed, by phonetic markedness, i.e., motor complexity, it may not be much use looking for the differences between markedness effects at both levels of processing, as they cannot be separated for analysis.

3. Fluent vs non-fluent aphasia and levels of processing

A broader classification of patients displaying phonological impairment than that described above (into Broca’s, conduction, and Wernicke’s aphasics) is through a division between fluent and non-fluent aphasia. In the absence of extralinguistic factors, such as dysarthria, non-fluent patients are generally claimed to suffer from difficulty in the timing and coordination of articulatory movements in speech (Blumstein et al. 1980; Blumstein 1991; Hough et al.
1994). This is related to a deficit at a cognitive phonetic level of processing (Code & Ball 1988). This level is quite peripheral to the language processing system, but it may still be considered linguistic and it is not so peripheral that symptoms of a deficit at this level can be ascribed merely to inadequate bucco-facial muscle strength. Articulatory muscles themselves are intact and all movements necessary for speech production can be correctly executed, but the problem lies in the adequate coordination of and voluntary control over the articulators. An even more cognitive approach says that non-fluent patients are impaired in translating the phonological speech plan into a phonetic plan, which should be fully specified for correct articulation (Code & Ball 1988). Such marginally different interpretations are difficult to disentangle (Code 1998; Croot et al. 1998). Non-fluent aphasics are mostly patients that would be classically diagnosed as suffering from Broca’s aphasia with apraxia of speech.

The label of fluent aphasia seems to cover a wider range of traditional syndromes. It includes lexical as well as postlexical disorders (Kohn 1988), for example the classical syndromes of Wernicke’s aphasia and conduction aphasia. What these disorders have in common is that they yield incorrect phonological plans. This may be caused by incorrect lexical access or representations, or by incorrect phonemic sequencing, the mapping of speech sounds and features onto metrical frames (i.e., phonological encoding). The difference, then, between fluent and non-fluent aphasics is that fluent aphasics create an erroneous phonological plan that may be correctly executed phonetically, whereas non-fluent aphasics incorrectly execute, or phonetically implement, a correct phonological speech plan.

Den Ouden & Bastiaanse (1999) argued that this division provides the opportunity to investigate whether certain structural markedness effects, such as preferred syllable structure, are the result of phonological or of phonetic level constraints. We studied the effects of positional syllable-internal markedness on the deletion patterns of segments in the paraphasias produced by fluent and non-fluent aphasics on a repetition task. On the basis of a syllable template with relatively strong and weak segment positions (van Zonneveld 1988), we predicted that in a word such as sprints /sprinz/, the segments printed in bold would be less susceptible to deletion than the others, if the factors responsible for positional syllable-internal markedness were active. The syllable template model itself was based on language typology (frequency of occurrence of structures) and data from child language acquisition (order of acquisition and tendencies within error patterns).
The graphs in Figure 1 show the results of the 9 fluent and the 6 non-fluent Dutch aphasic patients on the monosyllabic repetition task that was presented to them. The items in the task were all Dutch monosyllables, with different syllable structures, which, for analysis, were mapped onto the discussed syllable template. In this particular model, the onset and coda satellites (osat and csat) can only be filled with glides, liquids or nasals (i.e., sonorant consonants), the pre-margin (pre) can only be filled with the segment /s/ and the appendix (app) with coronal voiceless obstruents (/s/, /t/) or, in very rare (highly marked) cases, /k/ or /p/. The pre-margin and appendix positions can be considered extrasyllabic: they violate binary branching and their ‘behavior’ is exceptional in other ways as well (cf. Harris 1994). Positions dependent on other positions are only filled if the position they are dependent on is filled. For example, the pre-margin and the onset satellite are dependent on the onset core (ons). In this model, everything depends on the peak. The position for this peak (the vowel) is left out in these graphs, as the comparison was only between consonant positions. Vowels were hardly ever deleted in the monosyllabic repetition items.

The graphs display the number of deletions within a certain segment position, relative to the actual occurrence of that position in the items presented for repetition. Using the scores of individual patients, Wilcoxon tests were employed to calculate the significance of the difference in the mean proportions of deletions. The illustrative word used here is sprints, which did not actually occur in the item list itself, because it is morphologically complex in Dutch.

![Graphs showing deletion errors in different syllable positions](image)

**Fig. 1: Deletion errors in different syllable positions (Den Ouden & Bastiaanse 1999)**

Although the tendencies that are visible in these graphs show that the core onset and coda positions are least prone to deletion, significance was only reached for the difference between deletions in onset and onset satellite positions and between deletions in coda and appendix positions for both the fluent and the non-fluent patients. The fluent patients also deleted significantly more segments in appendix positions than in coda satellite positions. The overall
conclusion of this study was that the literal paraphasias of fluent and non-fluent aphasics show the influence of positional markedness on deletions.

Nevertheless, what remains is the fact that the proportions of deletions in coda and coda satellite positions differ less for fluent aphasics than for non-fluent aphasics, whereas there is no particular difference in onsets. This coda observation, as we choose to name it, may have been obscured by the particular template that we used and by the rules for associating particular segments to particular syllable slots. The data analysed in Den Ouden & Bastiaanse (1999) contain CVC syllables, in which a sonorant coda would be associated to the coda core position, as well as CVCVC and CVCCC syllables, which may blur the view on what happens to (pure) CC-onsets and CC-codas. For this reason, we decided to take a closer look at the relevant data, taking into account only those items with CC-onsets and/or CC-codas, in order to abstract away from influences by other structural positions as much as possible.

4. The Coda observation

In this section, the relevant data and the methods of collecting them are discussed. We analysed the responses to a subset of target items used in Den Ouden & Bastiaanse (1999). For this renewed visit to the repetition study, four more non-fluent patients were tested. The other patients and their data were taken from the previous, 1999 study.

4.1 The experimental investigation

Subjects were 10 non-fluent aphasics, 4 male and 6 female, with a mean age of 61 (range 50-79), and 9 fluent aphasics, 7 male and 2 female, with a mean age of 58 (range 38-84). The non-fluent patients had been diagnosed by their speech therapists as suffering from apraxia of speech, without dysarthria. This diagnosis was confirmed by the examiner. The fluent aphasics did not suffer from apraxia of speech.

All patients produced literal paraphasias on language tests and in spontaneous speech. All were native speakers of Dutch and more than 3 months aphasic due to a single left-hemispheric stroke.

The repetition task consisted of 114 Dutch monosyllabic words, of which 41 were analysed for the present study. These were the items with complex

---

3 The relatively high proportion of deletions in pre-margin position by non-fluent aphasics is explained by the fact that apraxics generally have problems with initiating movement (Code 1998). Non-fluent patients with apraxia of speech will have difficulty with the beginning of words, independently of syllable position (cf. Dogil & Mayer 1998). All syllable onsets in the monosyllabic items in the test obviously coincided with word onsets.
onsets or complex codas, which did not violate the sonority slope, meaning that the sonority value of segments rose from the margins to the peak (Clements 1990). This restriction bars /st/-onsets, for example. The restrictions on usable items left us with 21 items with complex onsets and 20 items with complex codas.

Deletions were scored per segment position within the analyzed onsets and codas. In onsets the opposition was between the onset core and the onset satellite, or, in this case, the first and the second position, respectively. In codas, the opposition was between the coda satellite (the first position) and the coda core (the second position). As an example, the word print is (orthographically) given below, with the appropriate position labels:

```
p      r      i      n      t
onset core  onset sat.  coda sat.  coda core
```

We wanted to know whether the two positions within a complex onset or coda were equally affected by syllable simplification errors. For this reason, we only took into account deletions of these positions, as they are the only true quantitative simplifications of phonological structure, as opposed to segment substitutions. Note that not all patients produced 41 valid responses to the 41 items under scrutiny, as target items yielding neologisms or no-responses were not included in the analysis.

All in all, the literal paraphasias of fluent aphasic patients and non-fluent aphasic patients were analyzed for the proportions of deletions per syllable position, in onsets and codas.

Results are summarized in Table 1 and in Figure 2. Table 1 shows the absolute number of deletions in the different positions. N is the total number of occurrences of relevant onset or coda clusters for this group of patients. The p-values printed in bold, based on χ²-tests, show significant differences (α=.05). The graphs in Figure 2 show the mean number of deletions, proportionate to the number of occurrences of the relevant position in the target list, for each group of patients.

---

4 In the more detailed sonority hierarchies that have been proposed, voiceless fricatives, such as /s/, are considered to be more sonorant than stops, such as /t/. Detailed sonority hierarchy (Jespersen 1904, cited in Clements 1990:285):

- low vowels > mid vowels > high vowels > r-sounds > laterals = nasals >
- voiced fricatives > voiced stops > voiceless fricatives > = voiceless stops

In less detailed hierarchies, with a stronger claim on universality, fricatives and stops are joined in the category of obstruents, with equal sonority values, the adjacency of which also does not make for a well-formed sonority slope.
Table 1: Deletions in onset and coda CC-clusters

<table>
<thead>
<tr>
<th>Onsets</th>
<th>deletions in onset core</th>
<th>deletions in onset sat.</th>
<th>N</th>
<th>$\chi^2$</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluent</td>
<td>4</td>
<td>16</td>
<td>186</td>
<td>X = 6.394</td>
<td>p = 0.0058</td>
</tr>
<tr>
<td>Non-fluent</td>
<td>16</td>
<td>30</td>
<td>206</td>
<td>X = 4.064</td>
<td>p = 0.0285</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Codas</th>
<th>deletions in coda sat.</th>
<th>deletions in coda core</th>
<th>N</th>
<th>$\chi^2$</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluent</td>
<td>13</td>
<td>11</td>
<td>178</td>
<td>X = 0.045</td>
<td>p = 0.6725</td>
</tr>
<tr>
<td>Non-fluent</td>
<td>30</td>
<td>13</td>
<td>198</td>
<td>X = 6.679</td>
<td>p = 0.0097</td>
</tr>
</tbody>
</table>

Fig. 2a: Deletions in onset clusters for fluent and non-fluent aphasic patients

Fig. 2b: Deletions in coda clusters for fluent and non-fluent aphasic patients
The graphs visualize the effects shown in Table 1, namely that the patterns of deletions are equal for both groups in onsets, but not in codas, where only the non-fluent patients delete the sonorant coda position (the coda satellite) significantly more often than the non-sonorant coda position (the coda core). For example, the non-fluent patients’ rendition of the target word print (/prɪnt/) will characteristically be [pɪɾt], while the fluent patients will turn it into either [pɪɾn] or [pɪɾt], in a seemingly random fashion. The ‘coda observation’ of Den Ouden & Bastiaanse (1999) thus holds true upon closer inspection.

4.2 Discussion
It is clearly not the case that only non-fluent aphasics show effects of markedness relations, while fluent aphasics reveal a random distribution of errors, as the effects are the same for both groups within onset clusters. For our account of these data, we return to the notion of markedness.

Jakobson’s markedness hierarchy was very much based on a contrast between segments and segment categories. In order to achieve the biggest contrast between vowels and consonants, consonants should be as consonantal as possible, and vowels should be as vowel-like as possible. According to this hierarchy of segmental markedness, consonants are less marked if they are less sonorant. Segmental markedness applies non-contextually; it does not take into account the position of a segment within a syllable. This markedness hierarchy can account for the error pattern of non-fluent patients, but not for the coda observation in fluent patients’ errors.

If we do look at segments in the context of prosodic structure, a different picture emerges. Clements (1990) argued that the preferred sonority slope of syllables has a steep rise in sonority pre-vocally and a slow decline in sonority postvocally. Syllables with sonorant codas are more frequent than syllables with non-sonorant codas. This Sonority Cycle (Clements 1990) allows us to formulate a second markedness hierarchy, which we will call syllable markedness, according to which onsets want to be non-sonorant and codas want to be sonorant.

The Sonority Cycle was indeed the object of investigation of Christman (1992), who showed that neologisms (produced by fluent patients) conform to this principle of a steep rise and a minimal decline of sonority in syllables, as formulated by Clements (1990). In a case study, Romani & Calabrese (1998) also investigated the influence of syllable complexity and segmental markedness on literal paraphasias. The Italian mother tongue of their patient, however, has so many restrictions on possible codas, that it does not allow for complex coda analysis in the way that Dutch or English might.
Syllable markedness alone cannot account for the pattern of deletions observed in fluent patients' paraphasias. Note, however, that segmental and syllable markedness reinforce each other in onsets, whereas they are in opposition in codas. It is this combination of the two types of markedness, or rather the crucial conflict between them, that may account for the error pattern of fluent aphasics.

Relating the two types of markedness to the results obtained in this study, our claim is that for non-fluent aphasic patients, who have a deficit at a (cognitive) phonetic level of speech production, segmental markedness is dominant. Irrespective of syllable position, these patients 'prefer' to delete sonorant consonants and to end up with non-sonorant consonants. Fluent aphasic patients, who have a deficit at or before the level of phonological encoding, show the influence of both segmental markedness and syllable markedness. For codas, this means that there is a conflict which results in a draw, hence the almost equal distribution of deletions of sonorant and non-sonorant consonants in this syllable constituent.

The full analysis of the presented data is therefore as follows: non-fluent aphasics have a deficit at a phonetic level of processing. At this level, where articulatory planning takes place, the markedness of individual segments, or feature combinations, is still an influential factor. The impairment allows this type of markedness to become dominant and this means that when clusters of consonants are reduced, the non-sonorant, segmentally least marked consonant will come out as the winner, irrespective of its position within a syllable.

Before this phonetic level of processing, constraints on sonority sequencing, i.e., on preferred syllable structure, are active beside constraints on segmental markedness. At the affected level(s) of processing in fluent aphasics, the conflict between segmental markedness constraints and syllable markedness constraints emerges, as structure-preserving constraints lose control over the output of the speech production process. This yields a pattern of errors in which onsets are relatively systematically reduced to non-sonorant segments, as both types of markedness reinforce each other in onsets, while codas are reduced on a seemingly random basis to either sonorant or non-sonorant segments, as the constraints are in direct conflict over what is a preferred coda.

The notion of a conflict between different phonological constraints on well-formedness makes it quite appealing to investigate the representation of the interaction of these constraints within the framework of OT, as this framework typically allows for constraints with opposing ends and as it has become the most influential phonological framework of the previous and of the current
decade. The remainder of this paper will be dedicated to the discussion of how the foregoing analysis may or should be represented in OT, the starting point being to stay as much as possible within the representational and conceptual limits set out by the still developing formal theory itself.

5. The coda observation in OT

Since its introduction in the early 1990s, OT has quickly gained ground in phonology, as it is presently doing in the domains of syntax and semantics. Its main appeal lies in two characteristics: the focus on well-formedness of the output, as opposed to a focus on rules that seem to exist for their own sake, and the softness of constraints, where a constraint can be violated in order to satisfy something more important.

Constraints on the well-formedness of the output, so-called markedness constraints, compete with each other and with structure-preserving faithfulness constraints. A grammar is formed by the language-specific ranking of these viable, universal constraints. An unrestricted number of possible candidates for the eventual output form of the utterance are generated by a component named GEN (Prince & Smolensky 1993). These output candidates are compared, on the basis of the input form and the ranked constraints. The output candidate that has the least important constraint violations wins and, consequently, is the optimal output. This optimal output may violate constraints, in order to satisfy higher ranked, i.e., more important, constraints.

There are two types of faithfulness constraints. Parse (or Max) constraints say that material in the input should also be present in the output. Such constraints block deletion. Fill (or Dep) constraints say that material in the output should also be present in the input, thus blocking insertion.

Another conspicuous characteristic of classic OT is that all constraints on the output should compete with each other at all times and that their hierarchical ranking is stable for adult speakers. This basically means that the ‘construction’ of the output occurs in one step. OT is therefore minimally derivational, the only derivation being that from the input to the output. If we consider, then, the focus on derivations and cyclicity of processes in previous decades (e.g., Kiparsky 1979), it is only logical that the main criticism of OT has been based on evidence that some phonological processes simply cannot be adequately described without making reference to some notion of cyclicity or multiple levels of processing.

Such criticism has led to a number of adaptations to the original theory, all aimed at giving satisfactory descriptions of morphophonological processes in which the output form seems to be opaque, and certain constraints appear to
have been applied only to specific substrings of the eventual output form (a phonological word, mostly) (cf. the contributions to Hermans and van Oostendorp 1999). Examples of such tools that aim to maintain the one-step evaluation are Output-Output Correspondence (McCarthy & Prince 1995), in which the optimal output form wants to be as similar as possible to other output forms it is related to, and Sympathy Theory (McCarthy 1998), in which the optimal output form wants to resemble a fairly arbitrarily chosen other output candidate. Other optimality theorists have chosen to abandon the one-step derivation and to incorporate some type of rule ordering in OT, allowing multiple levels of evaluation, with constraints that apply only to specific levels of processing, or stages in the derivation (Booij 1997; Rubach 2000). Crucially, the ‘founding fathers’ of OT, Prince & Smolensky (1993:79), did not put an absolute restriction on the theory as having only one level of evaluation, although the current practice in ‘standard’ OT is such that multiple levels of evaluation are considered a weakness.

Besides the discussion over single or multiple levels of evaluation in the formal theory, stands a large body of evidence for multiple levels of processing, from the fields of psycholinguistics and neurolinguistics, in which the issue is not under debate (see Levelt 1989, among many others). Lesion studies going back to the 19th century have shown that different parts of the brain perform different functions (for an overview, see Whitaker 1998). The only questions left to the field, with respect to this subject, are on the definition of ‘function’, whether there are direct, one-on-one relations between brain areas and specific functions and, if so, what areas perform which functions (Poeppel 1996a,b; Démonet et al. 1996). The domain of phonological processing itself has also been dissected (cf. Kohn 1988) and results of studies into temporally successive brain activity point towards a ‘phonological loop’ (Baddeley 1986) in which abstract and articulatory levels are distinct, though possibly mutually influential. OT should aim at ways to incorporate these multiple levels of (phonological) processing, instead of focusing on retaining the one-step hypothesis.

OT has not yet been applied in a systematic way to the study of language breakdown. However, for our purposes, it is worthwhile to consider the progress it is making in the field of child language acquisition, and consider the theoretical and representational questions raised in that domain of investigation (Stemberger & Bernhardt 1997; Barlow & Gierut 1999; Hayes 1999; Tesar & Smolensky 2000). The relation between aphasia and language acquisition has been sketched above and elsewhere (cf. Den Ouden & Bastiaanse, in press) and it is only natural to take it into account here.
5.1 OT and child language acquisition

Whether the constraints of language are considered to be innate and universal (Prince & Smolensky 1993) or not (Boersma 1998; Hayes 1999), or whether or not there are different rankings for production and perception, the general analysis of child language acquisition in OT terms is that children start off with a high ranking of markedness constraints and a low ranking of faithfulness constraints. This simply means that they will not be able to produce (or parse) the adult output forms of their mother tongue and that they will mainly show effects of markedness during the first stages of acquisition. Gradually, then, the markedness constraints will lower, relative to the faithfulness constraints, as the child tunes its grammar to that of its mother tongue (Stemberger & Bernhardt 1997). Communication becomes more accurate as the faithfulness constraints become more prominent. It is not the case that children will reset their constraint rankings on the basis of one single piece of positive evidence. Language acquisition, though fast, does not occur in one day, and children hear a lot of adult output forms on the basis of which they eventually set their grammar and optimize their lexicon. Also, during this process, there is much variation in their own output. Boersma (1998) therefore argues that this should be represented by variable distances between different constraints, which may at times even overlap. Thus, every piece of positive evidence (an adult output form) will cause a constraint to change position within the ranking, but this does not necessarily mean that it will immediately outrank another constraint; it may simply move closer. Constraints have a moving space within the hierarchy and as soon as constraint A comes within the scope of the space of constraint B, this means that both ranking A > B and B > A may occur, which accounts for variation in the output, if constraints A and B are in conflict. It is a common strategy in OT to capture optionality, also in adult grammars, by representing adjacent constraints as ranked freely with respect to each other (Clements 1997; Demuth 1997). OT applications to child language acquisition thus provide us with the tools to represent the domination of the unmarked and to represent variation or optionality.

5.2 OT and aphasia: constraints at different levels of processing

As noted in the above sections, aphasia is generally characterized by a prominence of unmarked structures. Compared to 'normal' speakers, the aphasic speaker is less faithful to the input, the input here being the lexicon or, for example, utterances to be repeated, whether real words or non-words. The most straightforward way of representing this in OT is by a lowering of faithfulness constraints, relative to markedness constraints. Note that it is theoretically also possible that the input itself is disturbed, so that the correct (i.e.,
adult) constraint ranking works on an incorrect input, or that the number and/or type of output candidates that are generated is in some way restricted. These options, however, do not directly account for the prominence of the unmarked, as observed in aphasic speech. Any systematic way of constricting the input or the output candidates would somehow have to be by incorporating extra markedness constrictions on these domains. This would come down to an extratheoretical add-on for which there is no evidence or argument in non-pathological natural language. We start from the hypothesis that language impairment is focal breakdown of the normal language system, crucially within its own terms. The impairment is assumed not to add new features to the normal system (cf. Caramazza 1991). The aphasic patients in this study show markedness effects in their impaired output, and our OT representation of this fact consists in the lowering of faithfulness constraints, which allows markedness constraints to have greater influence on the choice of the optimal output candidate. Aphasic data are never homogeneous. There is much noise and variability, which is precisely why statistics are used to determine whether some structures are significantly used more often than others. Variation, as we have seen above, can be represented by ‘switching’ of adjacent constraints. In an algorithm such as Boersma’s (1998), with unequal distances between different constraints in the hierarchy, there may be 100% overlap of constraint space, yielding a 50-50 distribution of two forms in a variable pattern, but it is also possible to conceive of a partial overlap, yielding a different distribution, with one of the two forms occurring more often than the other.

In this section, we present the OT tableau that represent our analysis of the data discussed here, viz. the coda observation. In reduction of consonant clusters, non-fluent patients will render the target word print (/prin/) as [pit], while fluent patients will turn it into either [pin] or [pit], in a seemingly random fashion. After the presentation and the explanation of the tableaux, we will go deeper into some considerations underlying our particular representation of the data. The constraints needed for this analysis are in (1):

(1) \begin{align*}
\text{Markedness} \quad & \text{Do not allow sonorant consonants} \\
*C[+\text{SON}] \quad & \text{Onsets do not want to be sonorant} \\
\text{HONS (Onset Harmony)} \quad & \text{Codas want to be sonorant} \\
\text{HCOD (Coda Harmony)} \quad & \text{Do not allow complex onsets or codas} \\
*\text{COMPLEX} \quad & \text{Preserve input material} \\
\text{Faithfulness} \quad & \\
\text{PARSE} \quad &
\end{align*}
GEN generates an infinite number of possible output candidates, most of which are rendered irrelevant because they are too deviant from the input form and therefore incur too many violations of faithfulness constraints. The candidates that we will consider in Table 2 are the most relevant to our data and to our example input form *print*, and we should be able to distinguish between them and choose the correct optimal output form with the constraints given above. Other possible candidates are dealt with by other constraints, but this is outside the scope of this paper. The data discussed all concern cluster reduction. This is represented by the ranking of *COMPLEX* over PARSE.

This ranking applies to both groups of patients, fluent and non-fluent. Table 2 shows how these two constraints and their ranking distinguish between the candidate outputs. The top left cell shows the input. The output candidates are given below that, in the first column. Constraint names are given in the top row, ordered by prominence in the hierarchy from left to right. A candidate’s violations of a constraint are marked with ‘**’ in the relevant cell. A crucial violation of a constraint, meaning that the candidate in question is no longer relevant for lower-ranked constraints, as others will always be more optimal, is marked with an exclamation mark ‘!’ to the right of which the irrelevant cells are grey. The winning, optimal candidate is marked with a pointed finger ‘*’.

<table>
<thead>
<tr>
<th>/print/</th>
<th>*COMPLEX</th>
<th>PARSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>print</td>
<td>** !</td>
<td></td>
</tr>
<tr>
<td>pint</td>
<td>* !</td>
<td></td>
</tr>
<tr>
<td>ptt</td>
<td></td>
<td>**</td>
</tr>
<tr>
<td>pm</td>
<td></td>
<td>**</td>
</tr>
<tr>
<td>rtt</td>
<td></td>
<td>**</td>
</tr>
<tr>
<td>rnt</td>
<td>* !</td>
<td></td>
</tr>
<tr>
<td>prnt</td>
<td>* !</td>
<td></td>
</tr>
<tr>
<td>prin</td>
<td>* !</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Ranking of *COMPLEX* over PARSE

The ranking in Table 2 yields four candidates, boldly printed in the tableau, between which the other relevant constraints should differentiate. Non-fluent patients will delete the non-sonorant consonants, regardless of their position within the syllable and we have argued that the constraint
responsible for this is one on segmental markedness, namely *C[+son]. The 
representation of the impairment of non-fluent patients, on the basis of our 
data, is therefore fairly straightforward (Table 3):

<table>
<thead>
<tr>
<th>/prnt/</th>
<th>*COMPLEX</th>
<th>PARSE</th>
<th>*C[+son]</th>
</tr>
</thead>
<tbody>
<tr>
<td>prnt</td>
<td>** !</td>
<td>**</td>
<td></td>
</tr>
<tr>
<td>pmt</td>
<td>** !</td>
<td>*</td>
<td>**</td>
</tr>
<tr>
<td>eF pt</td>
<td></td>
<td>**</td>
<td></td>
</tr>
<tr>
<td>ptn</td>
<td></td>
<td>**</td>
<td>* !</td>
</tr>
<tr>
<td>rtt</td>
<td></td>
<td>**</td>
<td>* !</td>
</tr>
<tr>
<td>rm</td>
<td></td>
<td>**</td>
<td>** !</td>
</tr>
<tr>
<td>rmt</td>
<td>** !</td>
<td>*</td>
<td>**</td>
</tr>
<tr>
<td>ptt</td>
<td>** !</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>prn</td>
<td>** !</td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Non-fluent patients: /prnt/ → [pt]

The fluent patients may turn example word *print* into either *ptn* or *ptt*. 
We have argued that this is because of a competition between a constraint on 
the preferred sonority value of the syllable constituent coda and a segmental 
markedness constraint that disallows sonorant consonants. With respect to 
these two constraints, HCOD and *C[+son], two rankings are possible, 
yielding different results, as shown in Table 4a and Table 4b.

<table>
<thead>
<tr>
<th>/prnt/</th>
<th>*COMPLEX</th>
<th>PARSE</th>
<th>*C[+son]</th>
<th>HCOD</th>
<th>HONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>prnt</td>
<td>** !</td>
<td>**</td>
<td></td>
<td>**</td>
<td></td>
</tr>
<tr>
<td>pmt</td>
<td>** !</td>
<td>*</td>
<td></td>
<td>**</td>
<td></td>
</tr>
<tr>
<td>eF pt</td>
<td></td>
<td>**</td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>ptn</td>
<td></td>
<td>**</td>
<td>* !</td>
<td></td>
<td></td>
</tr>
<tr>
<td>rtt</td>
<td></td>
<td>**</td>
<td>* !</td>
<td></td>
<td></td>
</tr>
<tr>
<td>rm</td>
<td></td>
<td>**</td>
<td>** !</td>
<td></td>
<td></td>
</tr>
<tr>
<td>rmt</td>
<td>** !</td>
<td>*</td>
<td>**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ptt</td>
<td>** !</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>prn</td>
<td>** !</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4a: Fluent patients: /prnt/ → [pt], [ptn]
Note that the specific ranking of HONS is irrelevant here, as long as it is ranked below *COMPLEX. HONS, as we have argued, merely ‘strengthens’ the effect of *C[+SON] on onsets. Following OT conventions, this non-crucial ranking with respect to other constraints is marked with a dotted line.

<table>
<thead>
<tr>
<th>/prɪnt/</th>
<th>*COMPLEX</th>
<th>PARSE</th>
<th>HCOD</th>
<th>*C[+SON]</th>
<th>HONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>prɪnt</td>
<td>**!</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>prɪt</td>
<td>*!</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ʃt</td>
<td>**</td>
<td>*!</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ʃɛ pm</td>
<td>**</td>
<td></td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>rɪt</td>
<td>**</td>
<td>*!</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rɪm</td>
<td>**</td>
<td></td>
<td>**!</td>
<td></td>
<td></td>
</tr>
<tr>
<td>rɪnt</td>
<td>*!</td>
<td></td>
<td></td>
<td>**!</td>
<td></td>
</tr>
<tr>
<td>prɪt</td>
<td>*!</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>prɪm</td>
<td>*!</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4b: Fluent patients: /prɪnt/ → [pt]: [pm]

We have now given an OT representation of our interpretation and analysis of the data discussed in this paper, viz. the coda observation. For fluent aphasics, the tableaux show competition between and switching of the constraint on segmental markedness and the constraint on preferred sonority value of codas. The tableau for non-fluent aphasics shows dominance of segmental markedness and either the absence, or the non-competitively low ranking of the constraint(s) representing the Sonority Cycle. Thus, the data of two groups of patients, with deficits at different levels of speech processing, are represented with two different tableaux. It will not come as a surprise to the reader that we argue that there is a relation between the different levels of processing and the different tableaux. This relation will be specified further below.

5.3 Considerations

In the analysis above, aphasia was represented as a lowering of faithfulness constraints and an increased instability of (markedness) constraints, causing switching of adjacent constraints. A major argument against an analysis in which different types of aphasia are represented only through structural reranking of markedness constraints is the fact that aphasic speech errors hardly ever violate the phonotactics of the mother tongue of the speaker, or, indeed, universal restrictions on well-formedness (see Buckingham 1992). This would be unexplained if markedness constraints changed
position in the hierarchy on a large scale. The adherence to (mother tongue) phonotactics points towards a lowering of faithfulness constraints only. However, the variation found in the patterns of paraphasias belonging to different types of aphasia, such as observed in this study and contra Blumstein’s (1973) hypothesis, acts as an argument against the mere lowering of faithfulness constraints in the representation of aphasia. To represent different aphasic symptoms only through different degrees of faithfulness lowering comes down to saying that aphasic ‘syndromes’, or rather, clusters of symptoms, only differ with respect to the degree of seriousness of impairment.

For these reasons, rather than claiming that the constraints HONS and HCOD are ranked non-competitively low at the level of impairment of non-fluent aphasics, we argue that they are non-existent at this level. In this way, we minimize the structural reranking of markedness constraints, while still being able to represent impairments at different processing levels, with different characteristics. This means, then, that our analysis allows for different levels of evaluation of constraints, where not all constraints are active (i.e., exist) at all levels. From a psycholinguistic and neurolinguistic perspective, this is the only natural way to conceive of linguistic processing, and we also point to the more formally optimality theoretic attempts we have cited to allow for multiple-step derivation by incorporating multiple levels of evaluation in OT, with the approach taken here is by no means incompatible. In psycholinguistic modeling, it is common practice to minimize the number of levels, modules or stages of processing to those necessary for an accurate representation of empirical findings. A similar principle, Level Minimalism, is formulated by Rubach (2000:313), for his modification of OT, Derivational Optimality Theory, which allows multiple levels of evaluation. Another principle he formulates to restrict the power of his framework is that of Reranking Minimalism: “[the] number of rerankings is minimal [...] reranking of constraints comes at a cost and needs to be argued for” (Rubach 2000:313). This principle is in line with our approach of unstable rankings to account for variation, but with level-specific constraints instead of structural reranking of markedness constraints to account for the influence of different factors at different levels of speech production processing.

The constraint *COMPLEX, which in our analysis is crucially present at the levels of impairment of both fluent and non-fluent patient groups, is formulated here in terms of syllable markedness. It therefore prevents us from claiming that it is syllable markedness that is active besides segmental markedness at the pre-phonetic level of processing and that at the phonetic
level of processing, only segmental markedness constraints are active. This is because we have chosen to follow the intuitive notion that the underlying cause of cluster reduction in the first place is the same for fluent and non-fluent aphasics, namely that syllable constituents prefer to be simple (cf. Gilbers & Den Ouden 1994). Although the assumption that all constraints on syllable markedness act as one group and are active at exactly the same levels is not necessarily true, our analysis would gain by a more straightforward division between constraints that work on different domains, at different levels of evaluation/processing. This ‘problem’ would be solved if *complex were to be conceived of as a constraint on, for example, adjacent segments, without making reference to syllable constituents. If, however, the formulation of the constraint is indeed similar to ‘consonants do not want to be adjacent to consonants’, the prediction is that there should be no difference between proportions of reductions within syllable constituents and across syllable constituents. This hypothesis needs to be tested.

6. Conclusion

On the basis of fluent aphasics’ and non-fluent aphasics’ responses to a monosyllabic real word repetition test, we have argued that there is a difference between the pre-phonetic and the phonetic level of processing. In our OT approach, the constraints responsible for the Sonority Cycle, as formulated by Clements (1990), are active only at pre-phonetic levels of evaluation, whereas a constraint on segmental markedness, saying that consonants should be as consonantal as possible (and therefore non-sonorant), is active at the pre-phonetic, as well as at the phonetic level.

Aphasia, in an OT approach, comprises the lowering of faithfulness constraints at the affected level of processing. This accounts for the different types of aphasia that are distinguished clinically. Also, aphasia is characterized by unstable ranking of close (adjacent) markedness constraints, which accounts for the high degree of variation found in aphasic error patterns. Along the lines of Boersma (1998), this could be conceived of as a widening of the moving space of constraints from their relatively fixed place in the hierarchy, which increases the opportunity for overlap of constraints. In our study, this overlap and thus switching of constraints was particularly visible in the paraphasias of fluent aphasics, at whose affected level of processing (pre-phonetic) a competition between segmental markedness (*Cf+Son) and syllable markedness (HcD) leads to variation in the output. Where the process of cluster reduction applies, fluent patients will render the example item print /printh/ as either [prit] or [pin], with an equal distribution of
deletion of the sonorant or the non-sonorant segment. It is our position that language breakdown in the form of aphasia provides a window on the workings of the language system. Linguistic theories should be able to deal with the view thus offered.

REFERENCES


Dogil, Grzegorz & Jörg Mayer. 1998 “Selective phonological impairment: A case of apraxia of speech”. *Phonology* 15:2.143-188


